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DETERMINATION OF NONPROPAGATION DISTANCES FOR 25-MM XM792 HEI-T CARTRIDGES

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This project was accomplished as part of the U.S. Army's Manufacturing Methods and Technology Program. The primary objective of this program is to develop, on a timely basis, manufacturing processes, techniques, and equipment for use (cont)

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As part of an Army-wide expansion and modernization program, safe separation distance criteria for the production of a family of 25-mm tank cartridges (M791 APDS-T, M792 HEI-T, and M793 TP-T) were studied, tested, and determined in a series of tests. Since all cartridges use the same assembly line and since the M792 contained the greatest quantity of explosive, the M792 was selected for determining the nonpropagation distance. The test program consisted of five phases, each simulating a component or cartridge location on the assembly line. (cont)

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18. SUPPLEMENTARY NOTES (cont)

in production of Army materiel. Test coordination and basic data reduction were accomplished by the ARRADCOM Resident Operations Office, National Space Technology Laboratories, NSTL Station, Mississippi. Both exploratory and confirmatory tests were conducted by the Hazards Range Support Unit of Computer Science Corporation of NSTL.

20. ABSTRACT (cont)

Each of the five phases was further subdivided into exploratory and confirmatory tests to determine and statistically confirm the established distances, with the following results: The type I explosive pellets (stacks of three) had a safe distance of 25.4 mm (1.0 in.), with a 6.16% propagation probability. The type II explosive pellets had a safe distance of 12.7 mm with a 6.85% propagation probability. The safe distances for the loaded body assemblies, fuzed projectiles, and complete cartridges, vertically oriented, were all 63.5 mm (2.5 in.), with 7.11%, 6.38%, and 6.85% propagation probabilities, respectively.

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INTRODUCTION

Background

At the present time, an Army-wide modernization and expansion program is underway for the purpose of upgrading existing, and developing new load-assemble-pack (LAP) facilities for explosive ammunition items. This effort will enable such facilities to achieve increased cost effectiveness and improved safety, as well as provide manufacturing facilities for new improved weaponry within existing LAP facilities.

An essential component of this program is the development of safe separation (nonpropagation) distance criteria for munition end items, subcomponents, and bulk explosives. These criteria will be used as the basis for the design of all new ammunition manufacturing facilities, as well as the modernization of existing ones.

This report therefore provides safety criteria to support these facility layouts and final line concept approvals. The family of 25-mm tank cartridges (XM791 APDS-T, XM792 HEI-T, and XM793 TP-T) are being assembled by Ford Aerospace and Communication Corporation, Ammunition Engineering Aeronutronic Division, Newport Beach, California, and also by Honeywell, Inc., Defense Systems Division, New Brighton, Minnesota. Since all these cartridges will use the same basic assembly line and since the 25-mm XM792 HEI-T cartridge contains the greatest amount of explosive materials, it was selected for determining the safe distance for the complete 25-mm cartridge family.

Objective

The primary objective of this program was to determine experimentally the safe separation distances between various configurations of fully loaded 25-mm XM792 HEI-T cartridges and their components, as they are transported on conveying systems. The data obtained from this program will help determine the safe separation distance between the units on the conveying system, conveyor speeds, and the rate of production of this family of 25-mm tank cartridges.

The overall program objective is to supplement and/or modify existing safety regulations, and criteria pertaining to the safe spacing of ammunition and other energetic materials in order to assist explosive loading plants in their LAP facility layouts for the most effective and economic man-machine relationship.

Criteria

This test program was implemented to determine the safe spacing of 25-mm XM792 HEI-T cartridges and their components under simulated loading plant conditions such that the effects of a major accidental detonation of a munition on the

assembly line would be limited to the immediate area or loading bay and would not be propagated to adjacent loading activities. Therefore, the only acceptable criteria to establish the safe separation distances is the nonpropagation of the donor detonation to the acceptors.

Due to the availability of sufficient quantities of the test cartridges and subcomponents, a five-unit test array was used for all test configurations. In this array, acceptance criteria was established as the nonfunctioning of the outer acceptors.

All separation distances cited in this report were measured between axial centerlines of the donor and the acceptor cartridges (or donor and acceptor subcomponents).

TEST CONFIGURATION

General

The test program consisted of five phases, each corresponding to component or cartridge assembly locations on the overall assembly line of the 25-mm XM792 HEI-T cartridge (fig. 1). These locations are as follows:

1. Between one of the prepelleting stations and the HEI charging station, a stack of three type I pellets, each containing 3.35 grams (52 gr) of HEI explosive. The three pellets were vertically stacked (fig. 2).

2. Between another prepelleting station and the HEI charging station, a single type II pellet containing 1.94 grams (30 gr) of HEI explosive mix (fig. 3).

3. Between the body charging station and the projectile fuzing station, the vertically-oriented loaded body assembly containing a reconsolidated 30.2 gram (1.07 oz) pellet of HEI explosive mix (fig. 4).

4. Between the projectile fuzing station and the cartridge case attachment station, and vertically-oriented projectile with the XM715E5 PDSD Fuze attached (fig. 5).

5. Between the cartridge case attachment station and packout operation, the complete 25-mm XM792 HEI-T cartridge, vertically oriented (fig. 6).

Each of the five portions was further subdivided into an exploratory and a confirmatory test phase which would, respectively, determine and then statistically establish the desired nonpropagation distance for each cartridge and subcomponent configuration.

Test Specimens

The test specimens used during the program were either subcomponents of, or completely assembled, 25-mm XM792 HEI-T cartridges, depending upon what portion of the assembly line was being simulated

The 25-mm XM792 HEI-T cartridge (fig. 6) provides high lethality against personnel, vehicles, and materials. Characteristics of the HEI-T cartridge are presented in table 1. This cartridge consists of an XM715E5 fuze, an HEI-T projectile, a tracer element, and a loaded cartridge case.

The XM715E5 fuze is a delayed arming, point detonating, self-destruct type which also features a graze impact sensitivity against hard and soft ground media, as well as a superquick functioning upon direct target impact.

The HEI-T projectile (fig. 4) consists of a metal parts assembly, an explosive charge, and a tracer element. The metal parts assembly is a C1040 steel body and an electromagnetic iron bar rotating band, both given a protective phosphate coating prior to cavity and exterior painting. The explosive charge is 30.2 grams (1.07 oz) of H-761 high explosive incendiary mix reconsolidated from nine 3.35 gram (52 gr) and one 1.95 gram (30 gr) pellets using the composition shown in table 2. The tracer consists of three reconsolidated pellets made of compositions shown in table 2. The tracer is retained in the projectile body by crimping a stainless steel closure disk sandwiched between two steel metering rings over the tracer's exposed end.

The loaded cartridge case consists of a steel cartridge case body, an M115 percussion primer, an ignition booster pellet, and the double-base ball powder propellant. The cartridge case is loaded with between 87 and 92 grams (3.07 and 3.24 oz) of propellant with burning properties controlled by the physical shape and size of the propellant and by the chemical process employed in manufacture.

Test Arrangements

During each test phase, the general test array consisted of a centrally located donor and four acceptor specimens (fig. 7). The specimens were raised off the ground to simulate the height of an assembly line off the loading building floor. This configuration produced two sets of acceptor test data results for each detonation. The separation distances between the donor and acceptor specimens were not only varied during exploratory tests but were also varied within individual tests. However, for the confirmatory test phase, this distance was always held constant. Also, the distances were always the same between acceptors on one side of the donor during a particular test. For example, the test distance used from the donor (no. 3, fig. 7) to the inner left acceptor (no. 2) was also the distance between acceptors 1 and 2.

Type I pellets

The first phase was the determination of the nonpropagation distance between units, each consisting of three type I pellets (fig. 2). A series of exploratory and confirmatory tests were planned, each to use the general test array (fig. 7), in which each three-pellet stack was positioned vertically, with the donor and acceptor stacks in an inline and parallel array. A total of 12 exploratory tests were conducted at separation distances (measured centerline to centerline between the stacked pellets) ranging from zero spacing to 76.2 mm (3.0 in.), followed by a confirmatory test phase consisting of a series of 25 tests using the identical test array as that in the exploratory phase, with the centerline distances held constant to compile the necessary statistical data. A pretest view of the pellet stack configuration for a typical test detonation is shown in figure 8. This test series was conducted on a 1.27 cm (0.5 in.) thick steel witness plate to determine both donor detonation and type of acceptor propagation.

Type II pellets

The second phase was the determination of the nonpropagation distance between units, each consisting of a single type II pellet (fig. 3). Again, a series of exploratory and confirmatory tests were planned and executed. This time, only three exploratory tests were conducted, at separation distances, measured centerline to centerline between the pellets, which ranged from zero spacing to 76.2 mm (3.0 in.). These tests were followed by 25 confirmatory tests, using the identical test array as that in the exploratory phase, with the centerline distances held constant in order to compile the necessary statistical data. A pretest view of the pellet stack configuration for a typical test detonation is shown in figure 9. As in the type I pellet tests, this test series also used steel witness plates to determine both donor detonation and type of acceptor propagation.

Loaded Body Assembly

The third phase was the determination of the nonpropagation distance between loaded projectile body assemblies positioned vertically--open end (nose) in upward position--also on a steel witness plate to insure accurate interpretation of the test results. This test series consisted of six exploratory tests at centerline distances ranging from zero spacing to 76.2 mm (3.0 in.), which were followed by 25 confirmatory tests using the identical test array as that in the exploratory phase, with the centerline distances held constant in order to compile the necessary statistical data. A pretest view of the loaded body assembly test configuration for a typical test detonation is shown in figure 10.

Fuzed Projectile

The fourth phase was the determination of the nonpropagation distance between fuzed projectiles positioned vertically, fuze end up, on steel witness plates. The test series consisted of six exploratory tests at centerline distances ranging from 50.8 to 76.2 mm (2.0 to 3.0 in.), which were followed by 25 confirmatory tests using the identical test array as that in the exploratory phase, with the centerline distances held constant in order to compile the necessary statistical data. A pretest view of the fuzed projectile test configuration for a typical test detonation is shown in figure 11.

Complete XM792 Cartridge

The fifth and final phase was the determination of the nonpropagation distance between complete XM792 cartridges positioned vertically, fuze end up, on steel witness plates. This test series consisted of five exploratory tests at centerline distances ranging from zero spacing to 76.2 mm (3.0 in.), which were followed by 25 confirmatory tests using the identical test array as that in the exploratory phase, with the centerline distances held constant in order to compile the necessary statistical data. A pretest view of the complete XM792 cartridge test configuration for a typical test detonation is shown in figure 12.

Method of Initiation

The donor specimen (detonated sample) in each of the five test configurations was primed and initiated with an engineer's special J2 blasting cap without any kind of a boosting charge being used. In the first two phases, the blasting cap was positioned vertically above the donor specimens of the type I and II pellets. In the third phase, the blasting cap was inserted in the fuze cavity in the loaded body assembly. In the fourth and fifth phases, the blasting cap was inserted in the fuze cavity after removal of the donor specimen's fuze. This method of donor initiation insured that the donor specimen, in all cases, always detonated high-order, which was further confirmed by the examination of the steel witness plates after detonation.

TEST RESULTS

Type I Pellets

A total of 12 exploratory tests were conducted on the test array in which each specimen consisted of three each type I pellets stacked vertically. Exploratory test spacings, centerline to centerline, varied from a minimum of zero spacing to a maximum of 76.2 mm (3.0 in.), with high-order propagations to the outer acceptors occurring up to a distance of 12.7 mm (0.5 in.). A posttest view

of a steel witness plate used for two type I pellet tests is shown in figure 13. In both tests, the donor imprint stands out. The upper test imprint indicates a degrading detonation as the imprints fade out, whereas, in the lower test imprints, the entire left set of acceptors propagated high-order and the right acceptors had a degrading detonation.

The confirmatory tests on the type I pellet stacks were conducted at a safe spacing of 25.4 mm (1.0 in.), with a total of 25 firings taking place. Using the five-portion test array, this procedure yielded a total of 50 confirmatory test data points. Adding to this the four exploratory test firings at the same spacing, a total of 59 valid data points were produced at the safe nonpropagation spacing. A listing of the individual results of the type I pellet tests is shown in table 3.

Type II Pellets

Only three exploratory tests were conducted on the type II pellet array, in which the centerline distances were varied from a minimum of zero spacing to a maximum of 76.2 mm (3.0 in.). High-order detonation propagation only occurred at the zero spacing; therefore, all 25 confirmatory tests were conducted at a spacing of 12.7 mm (0.5 in.). The 25 confirmatory tests, plus one exploratory test at the same spacing, yielded a total of 52 valid data points as the safe nonpropagation spacing. A listing of the individual results of the type II pellet tests is shown in table 4. A posttest view of a steel witness plate used in the type II pellet tests is shown in figure 14.

Loaded Body Assembly

A total of six exploratory tests were conducted on the loaded body assembly array, in which the centerline distances were varied from a minimum of zero spacing to a maximum of 76.2 mm (3.0 in.). Propagation of the donor detonations to the outer acceptors occurred at spacings up to 38.1 mm (1.5 in.); thus, the 25 confirmatory tests were conducted at a spacing of 63.5 mm (2.5 in.). These 25 confirmatory tests, as summarized individually in table 5, represent 50 valid data points. A posttest view of four acceptors of a typical loaded body assembly test is shown in figure 15. The inner acceptors sustained various degrees of damage, from rupturing (left inner) to fragment impacts (right inner); however, both left and right outer acceptors were relatively undamaged.

Fuzed Projectile

A total of six exploratory tests were conducted on the fuzed projectile, in which the centerline distances were varied from a minimum of 50.8 mm (2.0 in.) to a maximum of 76.2 mm (3.0 in.). Propagation of the donor detonations to the outer acceptors only occurred at the 50.8 mm (2.0 in.) spacing; therefore, the 25 confirmatory tests were conducted at a spacing of 63.5 mm (2.5 in.). These 25

confirmatory tests, plus three exploratory tests at the same spacing, represent a total of 56 valid data points, as summarized in table 6. A posttest view of four acceptors of a typical fuzed projectile test is shown in figure 16. As in the loaded body assembly tests, the inner acceptors sustained all the damage, whereas the outer acceptors were undamaged; however, on all four acceptor projectiles, the fuzes were sheared off.

Complete Cartridge

A total of five exploratory tests were conducted on the complete XM792 cartridge array, in which the centerline distances were varied from a minimum of zero spacing to a maximum of 76.2 mm (3.0 in.). Although propagation of the donor detonation only occurred at the zero spacing, sufficiently heavy damage was sustained by the outer acceptors up to the 50.8 mm (2.0 in.) spacing--indicating that it was only a matter of sufficient testing before high-order propagation occurred. Therefore, the 25 confirmatory tests, plus a single exploratory test, were conducted at a spacing distance of 63.5 mm (2.5 in.), and represent a total of 52 valid data points as summarized in table 7. A posttest view of the results of a typical complete XM792 cartridge test is shown in figure 17. The outer acceptors were relatively undamaged (only the fuze sheared off on the left acceptor), whereas the inner acceptors had heavy damage on the left acceptor and a low-order detonation of the right acceptor. Also, although the donor cartridge had its projectile initiated to a high-order detonation, its cartridge case was not fully consumed.

Analysis of Test Results

Variations in manufacturing tolerances, materials, wear, etc., required that statistical reasoning be employed in the interpretation of the confirmatory test data. The actual probability of a continuous propagation of an unexpected explosive incident on a LAP line is a function of the number of propagation occurrences in a particular test portion as related to the total number of test detonations conducted (see appendix for statistical theory).

In the first hardware configuration test series, (three each type I pellets stacked vertically), a total of 58 observations were recorded at the 25.4 mm (1.0 in.) safe separation distances, resulting in an upper limit of 6.16% probability of propagation of an explosive incident at the 95% confidence level.

The test series using single type II pellets (second hardware configuration) had a total of 52 observation data points at the 12.7 mm (0.5 in.) safe separation distance, resulting in an upper limit of 8.85% probability of propagation at the 95% confidence level.

In the third hardware configuration, (vertically oriented, loaded-body assemblies), a total of 50 valid data points were produced at the 63.5 mm (2.5 in.) safe separation distance, resulting in an upper limit of 7.11% probability of propagation of an explosive incident at the 95% confidence level.

The test series using vertically-oriented fuzed projectiles (fourth hardware configuration) had a total of 56 recorded observations at the 63.5 mm (2.5 in.) safe separation distance, resulting in an upper limit of 6.38% probability of propagation of an explosive incident at the 95% confidence level.

The fifth and final hardware configuration, vertically-oriented complete cartridges, had a total of 52 observations recorded at the 63.5 mm (2.5 in.) safe separation distance, resulting in an upper limit of 6.85% probability of propagation of an explosive incident at the 95% confidence level.

These values are equivalent to stating that, in a large number of tests, 95 out of 100 times, the probability of an unexpected explosive incident propagating to a catastrophic event will be less than, or equal to, the values stated above, as summarized in table 8. These values indicate the quality of the test results and the reliance that can be placed upon the conclusions drawn from the data.

CONCLUSIONS

The minimum nonpropagation distance for vertical stacks, each containing three type I explosive pellets is 35.4 mm (1.0 in.), with the probability of the propagation of an explosive incident being 6.16% at the 95% confidence level. Also, the minimum nonpropagation distance for single type II pellets is 12.7 mm (0.5 in.), with the probability of the propagation of an explosive incident being 6.85% at the 95% confidence level.

The minimum nonpropagation distances for vertically-oriented loaded body assemblies, fuzed projectiles, and complete cartridges are all 63.5 mm (2.5 in.), with the probability of the propagation of an explosive incident being 7.11, 6.38, and 6.85%, respectively, at the 95% confidence level.

Table 1. Physical characteristics of 25-mm XM792 HEI-T cartridge

Item	Physical Characteristic	
Cartridge Weight	497.0 g	(1.09 lb)
Cartridge maximum diameter	3.81 cm	(1.50 in.)
Cartridge maximum length	21.92 cm	(8.63 in.)
Projectile weight	183.0 g	(6.45 oz)
Projectile maximum diameter	2.49 cm	(0.98 in.)
Projectile maximum length	9.42 cm	(3.71 in.)
Rotating band diameter	2.67 cm	(1.05 in.)
Projectile metal parts weight	131.0 g	(4.62 oz)
Explosive (HEI maximum) weight	30.2 g	(1.07 oz)
Propellant weight	91.0 g	(3.21 oz)
Fuze type	XM715E5 PDSD	
Self-destruct time	6.2 to 16.8 seconds	
Tracer burn time	4.2 seconds	

Table 2. Chemical compositions of 25-mm XM792 HEI-T cartridge

High explosive incendiary mix:

Item	% by weight
97/3 RDX/wax	64
Aluminum powder	35
Graphite and/or calcium stearate	1

Tracer composition:

Item	Pellet types (% by weight) Type III igniter	Type II transition	Type I sustainer
Magnesium (16 granulation)	-	50.0	50.0
Magnesium (five-micron size)	54.0	-	-
PTFE	30.0	20.0	20.0
VITON-A	16.0	7.0	7.0
Strontium nitrate	-	20.0	20.0
Graphite	1.0	-	-
Carbon black	-	3.0	1.0
Ethyl cellulose	-	2.0	2.0
Weight:			
grams	0.39	0.70	1.25
grains	6.01	10.80	19.29

Table 3. Test results - 25-mm XM792 HEI-T cartridge

(three type I pellets - stacked)

Test no.	Acceptors	Separation mm	Separation in.	Results*
		EXPLORATORY TESTS		
1	Left	76.2	3.0	2 and 1 NDP; 2 broke in process
	Right	76.2	3.0	4 and 5 NDP; 4 broke in process
2	Left	25.4	1.0	2 and 1 NDP; 2 pulverized
	Right	25.4	1.0	4 and 5 NDP; 4 pulverized
3	Left	Specimens touching		2 and 1 HOD
	Right	Specimens touching		4 and 5 HOD
4	Left	25.4	1.0	2 and 1 NDP; 2 pulverized
	Right	25.4	1.0	4 and 5 NDP; 4 pulverized
5	Left	25.4	1.0	2 and 1 NDP; 2 broke in process
	Right	25.4	1.0	4 and 5 NDP; 4 pulverized
6	Left	25.4	1.0	2 and 1 NDP; 2 pulverized
	Right	25.4	1.0	4 and 5 NDP; 4 pulverized
7	Left	12.7	0.5	2 HOD; 1 NDP, pulverized
	Right	12.7	0.5	4 HOD; 5 NDP, pulverized
8	Left	12.7	0.5	2 HOD; 1 NDP, pulverized
	Right	12.7	0.5	4 HOD; 5 NDP, pulverized
9	Left	12.7	0.5	2 and 1 NDP; 2 pulverized
	Right	12.7	0.5	4 and 5 NDP; 4 pulverized
10	Left	12.7	0.5	2 and 1 NDP; 2 pulverized
	Right	12.7	0.5	4 HOD; 5 NDP, pulverized
11	Left	12.7	0.5	2 and 1 NDP; 2 pulverized
	Right	12.7	0.5	4 and 5 NDP; 4 pulverized
12	Left	12.7	0.5	2 and 1 NDP; 2 pulverized
	Right	12.7	0.5	4 and 5 HOD
		CONFIRMATORY TESTS		
13 through 37	Left	25.4	1.0	2 and 1 NDP
	Right	25.4	1.0	4 and 5 NDP

Table 3. (cont)

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* NOTES

1. Numbers refer to order of position from left to right: acceptor 1, acceptor 2, donor 3, acceptor 4, and acceptor 5.

2. NDP = no detonation propagation.

3. Broken = pellet broken into large pieces.

4. Pulverized = pellet completely broken up into a fine powder.

5. HOD = high-order detonation.

Table 4. Test results - 25-mm XM792 HEI-T cartridge

(one type II pellet)

Test no.	Acceptors	Separation mm	Separation in.	Results*
		EXPLORATORY TESTS		
1	Left	76.2	3.0	2 and 1 NDP; 2 pulverized
	Right	76.2	3.0	4 and 5 NDP; 4 pulverized
2	Left	12.7	0.5	2 and 1 NDP, both pulverized
	Right	12.7	0.5	4 and 5 NDP, both pulverized
3	Left	Specimens touching		2 and 1 HOD
	Right	Specimens touching		4 and 5 HOD
		CONFIRMATORY TESTS		
4 through 28	Left	12.7	0.5	2 and 1 NDP
	Right	12.7	0.5	4 and 5 NDP

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* NOTES

1. Numbers refer to order of position from left to right: acceptor 1, acceptor 2, donor 3, acceptor 4, and acceptor 5.

2. NDP = no detonation propagation.

3. Pulverized = pellet completely broken up into a fine powder.

4. HOD = high-order detonation.

Table 5. Test results - 25-mm XM792 HEI-T cartridge

(loaded body assembly)

Test no.	Acceptors	Separation mm	Separation in.	Results*
		EXPLORATORY TESTS		
1	Left	76.2	3.0	2 and 1 NDP; 2 light damage
	Right	76.2	3.0	4 and 5 NDP, 4 light damage
2	Left	38.1	1.5	2 and 1 HOD
	Right	38.1	1.5	4 and 5 HOD
3	Left	Specimens touching		2 and 1 HOD
	Right	Specimens touching		4 and 5 HOD
4	Left	38.1	1.5	2 and 1 HOD
	Right	38.1	1.5	4 and 5 HOD
5	Left	76.2	3.0	2 and 1 NDP; 2 split
	Right	76.2	3.0	4 and 5 NDP; 4 split
6	Left	76.2	3.0	2 and 1 NDP; 2 split
	Right	76.2	3.0	4 and 5 NDP; 4 split
		CONFIRMATORY TESTS		
7 through 31	Left	63.5	2.5	2 and 1 NDP
	Right	63.5	2.5	4 and 5 NDP

* NOTES

1. Numbers refer to order of position from left to right: acceptor 1, acceptor 2, donor 3, acceptor 4, and acceptor 5.

2. NDP = no detonation propagation.

3. HOD = high-order detonation.

4. Split = projectile cracked by donor fragments.

5. Light damage = some fragment impacts but no penetrations.

Table 6. Test results - 25-mm XM792 HEI-T cartridge

(fuzed projectile)

Test no.	Acceptors	Separation mm	Separation in.	Results*
		EXPLORATORY TESTS		
1	Left	76.2	3.0	2 and 1 NDP; 2 ruptured
	Right	76.2	3.0	4 LOD; 5 NDP, ruptured
2	Left	50.8	2.0	2 and 1 HOD
	Right	50.8	2.0	4 and 5 HOD
3	Left	76.2	3.0	2 and 1 NDP; 2 ruptured
	Right	76.2	3.0	4 and 5 NDP; 4 ruptured
4	Left	63.5	2.5	2 and 4 NDP; 2 ruptured
	Right	63.5	2.5	4 and 5 NDP; 4 ruptured
5	Left	63.5	2.5	2 and 1 NDP; 2 ruptured
	Right	63.5	2.5	4 and 5 NDP; 4 ruptured
6	Left	63.5	2.5	2 and 1 NDP; 2 ruptured
	Right	63.5	2.5	4 and 5 NDP; 4 ruptured
		CONFIRMATORY TESTS		
7 through 14	Left	63.5	2.5	2 and 1 NDP
	Right	63.5	2.5	4 and 5 NDP
15	Left	63.5	2.5	2 LOD; 1 NDP
	Right	63.5	2.5	4 and 5 NDP
16 through 19	Left	63.5	2.5	2 and 1 NDP
	Right	63.5	2.5	4 and 5 NDP
20	Left	63.5	2.5	2 and 1 NDP
	Right	63.5	2.5	4 LOD; 5 NDP
21 through 27	Left	63.5	2.5	2 and 1 NDP
	Right	63.5	2.5	4 and 5 NDP
28	Left	63.5	2.5	2 and 1 NDP
	Right	63.5	2.5	4 LOD; 5 NDP
29 through 31	Left	63.5	2.5	2 and 1 NDP
	Right	63.5	2.5	4 and 5 NDP

Table 6. (cont)

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* NOTES

1. Numbers refer to order of position from left to right: acceptor 1, acceptor 2, donor 3, acceptor 4, and acceptor 5.

2. NDP = no detonation propagation.

3. Ruptured = metal parts broken up; explosive scattered but not consumed.

4. LOD = low-order detonation.

5. HOD = high-order detonation.

Table 7. Test results - 25-mm XM792 HEI-T cartridge

(complete cartridge)

Test no.	Acceptors	Separation mm	Separation in.	Results*
		EXPLORATORY TESTS		
1	Left	76.2	3.0	2 and 1 NDP; 2 medium damage
	Right	76.2	3.0	4 and 5 NDP, medium damage
2	Left	50.8	2.0	2 and 1 NDP; 2 heavy damage
	Right	50.8	2.0	4 LOD; 5 NDP
3	Left	Specimens touching		2 and 4 HOD
	Right	Specimens touching		4 HOD; 5 NDP, heavy damage
4	Left	50.8	2.0	2 and 1 NDP; 2 heavy damage
	Right	50.8	2.0	4 and 5 NDP; 4 medium damage
5	Left	63.5	2.5	2 and 1 NDP; 2 light damage
	Right	63.5	2.5	4 and 5 NDP; 4 light damage
		CONFIRMATORY TESTS		
6 through 12	Left	63.5	2.5	2 and 1 NDP
	Right	63.5	2.5	4 and 5 NDP
13	Left	63.5	2.5	2 and 1 NDP
	Right	63.5	2.5	4 LOD; 5 NDP
14 through 16	Left	63.5	2.5	2 and 1 NDP
	Right	63.5	2.5	4 and 5 NDP
17	Left	63.5	2.5	2 LOD; 1 NDP
	Right	63.5	2.5	4 and 5 NDP
18 through 30	Left	63.5	2.5	2 and 1 NDP
	Right	63.5	2.5	4 and 5 NDP

* NOTES

1. Numbers refer to order of position from left to right: acceptor 1, acceptor 2, donor 3, acceptor 4, and acceptor 5.

2. NDP = no detonation propagation.

3. Medium damage = cartridge case and/or projectile penetrated and/or cracked.

Table 7. (cont)

4. Heavy damage = cartridge case and projectile both ruptured, spilling propellant and explosives, respectively.

5. LOD = low-order detonation.

6. HOD = high-order detonation.

7. Light damage = cartridge case and projectile separated from each other; some fragment impacts but no penetration.

Table 8. Test results - 25-mm XM792 HEI-T cartridge

Hardware configuration	Number of tests	Separation mm	Separation in.	Probability (%)
Type I pellets, 3 each	58	25.4	1.0	6.16
Type II pellet	52	12.7	0.5	6.85
Loaded body assembly	50	63.5	2.5	7.11
Fuzed projectile	56	63.5	2.5	6.38
Complete cartridge	52	63.5	2.5	6.85

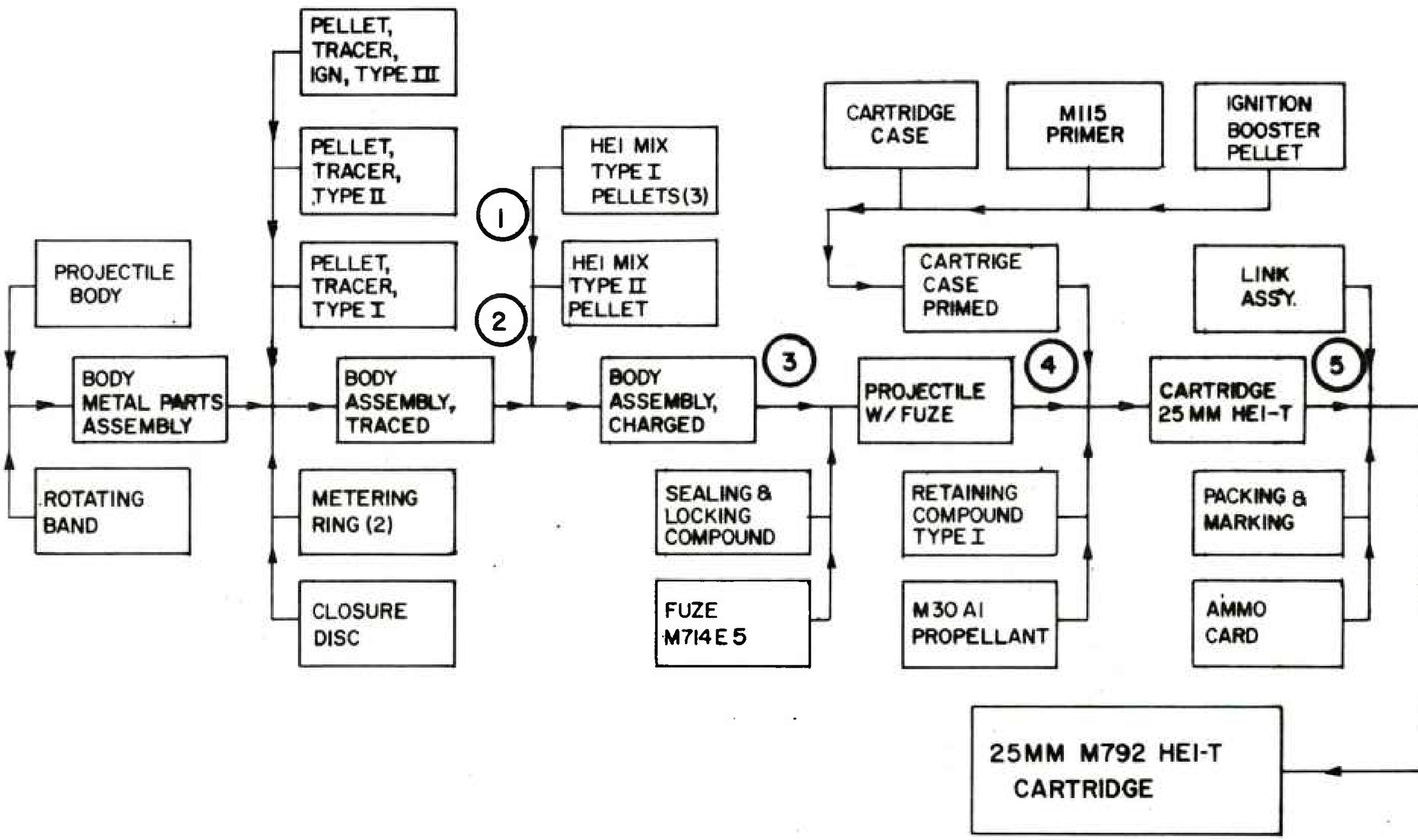

Figure 1. Production flow

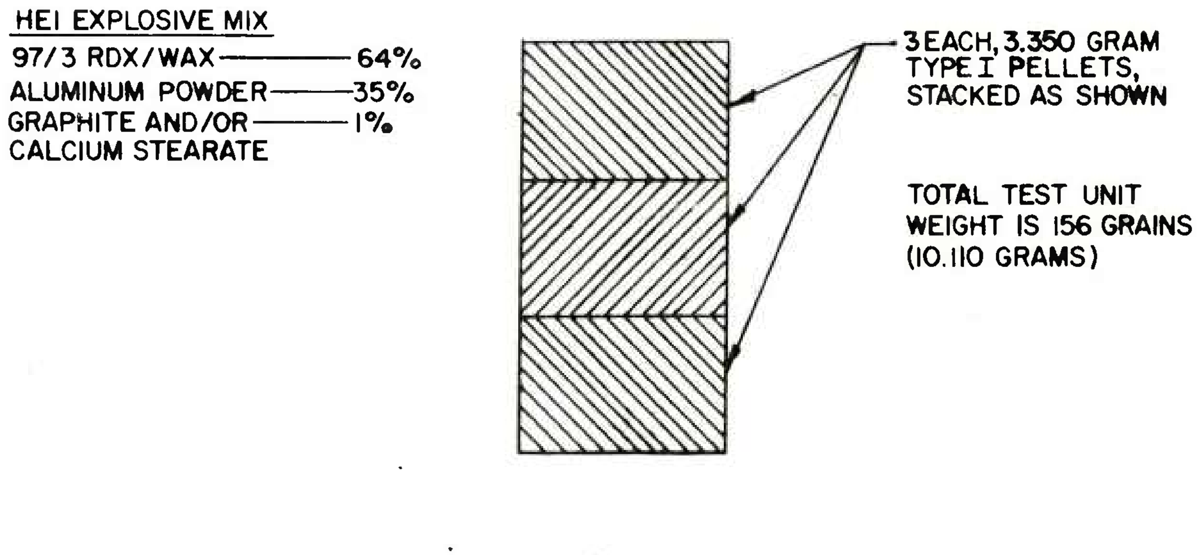

Figure 2. Three-pellet stack (test phase 1)

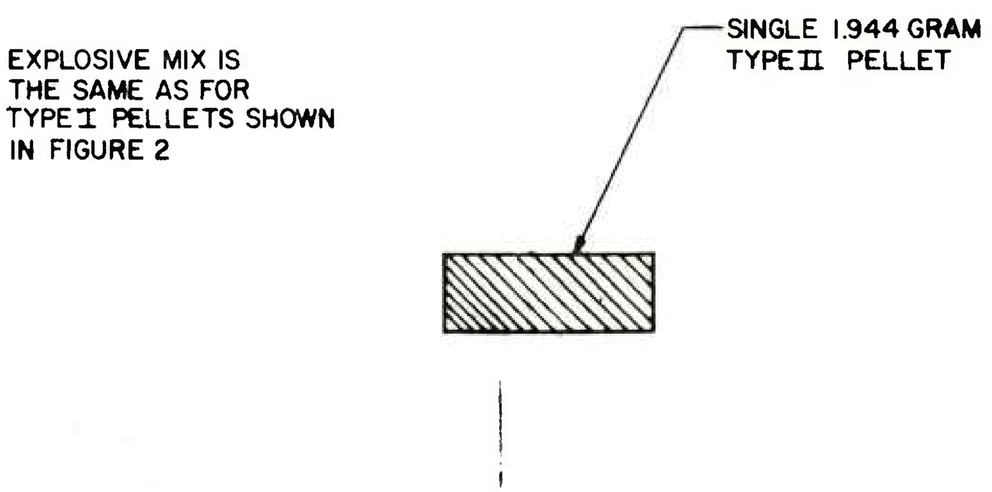

Figure 3. Single pellet (test phase 2)

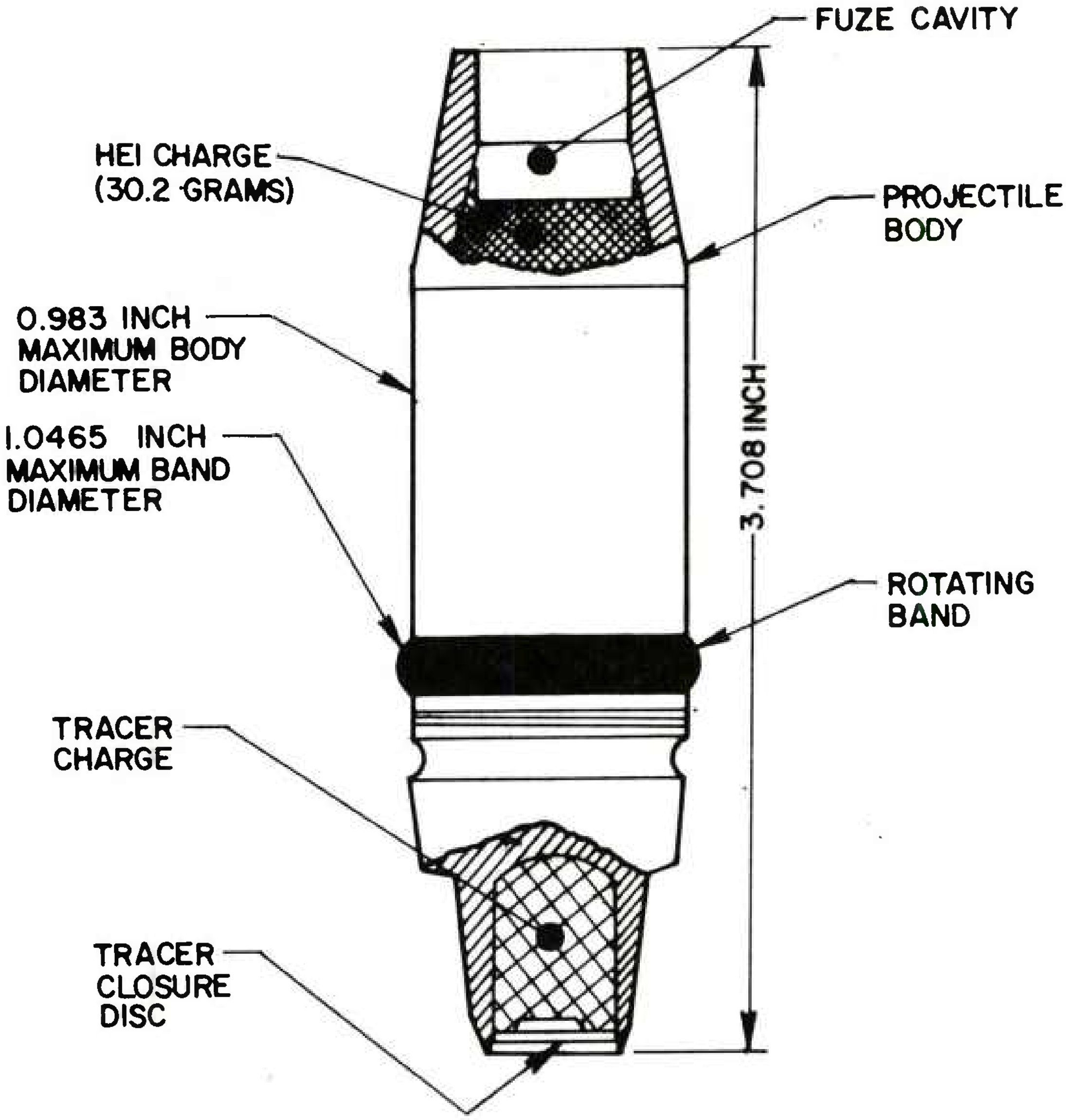

Figure 4. Loaded body assembly (test phase 3)

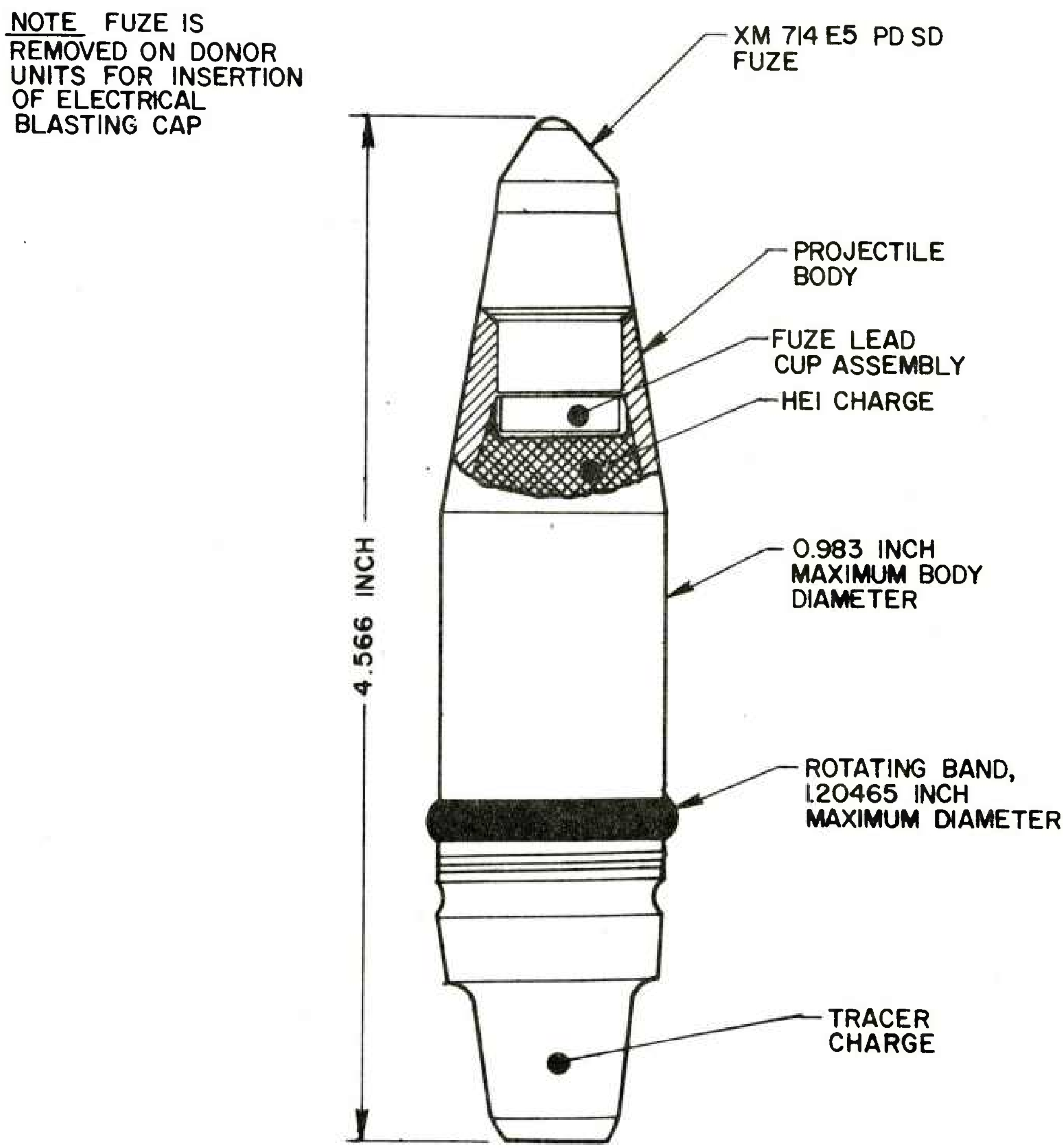

Figure 5. Fuzed projectile (test phase 4)

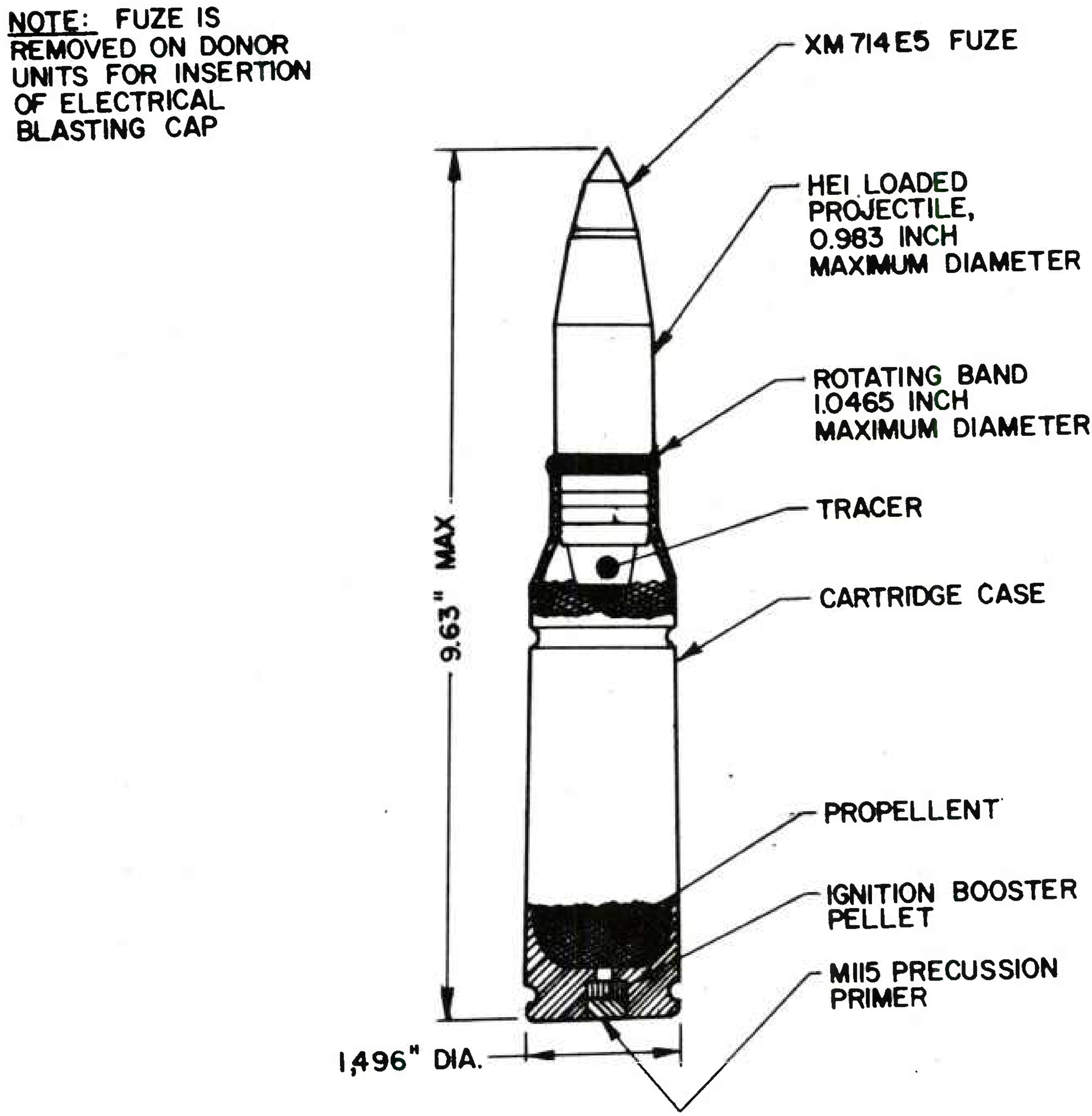

Figure 6. Complete cartridge (test phase 5)

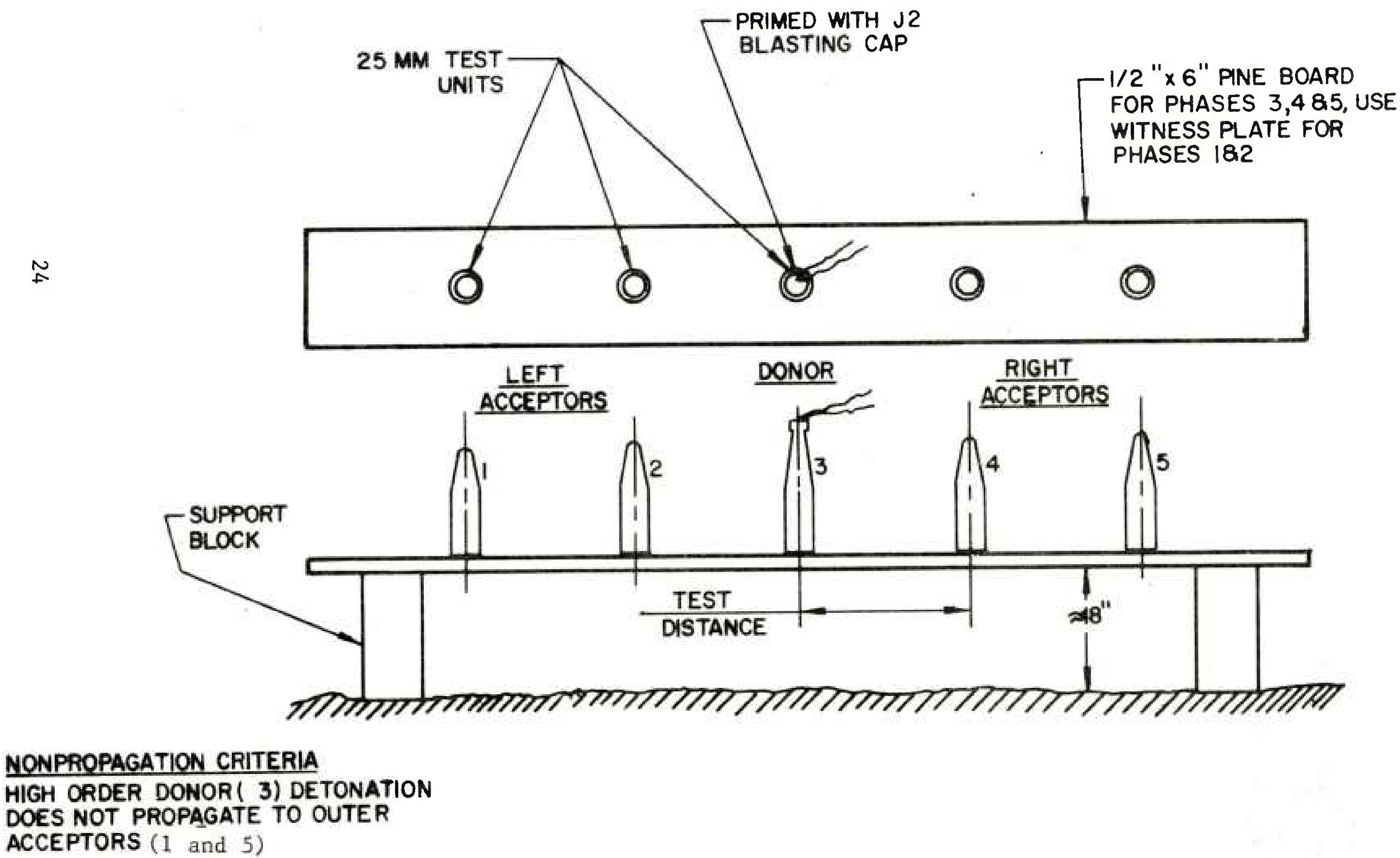

Figure 7. General test array

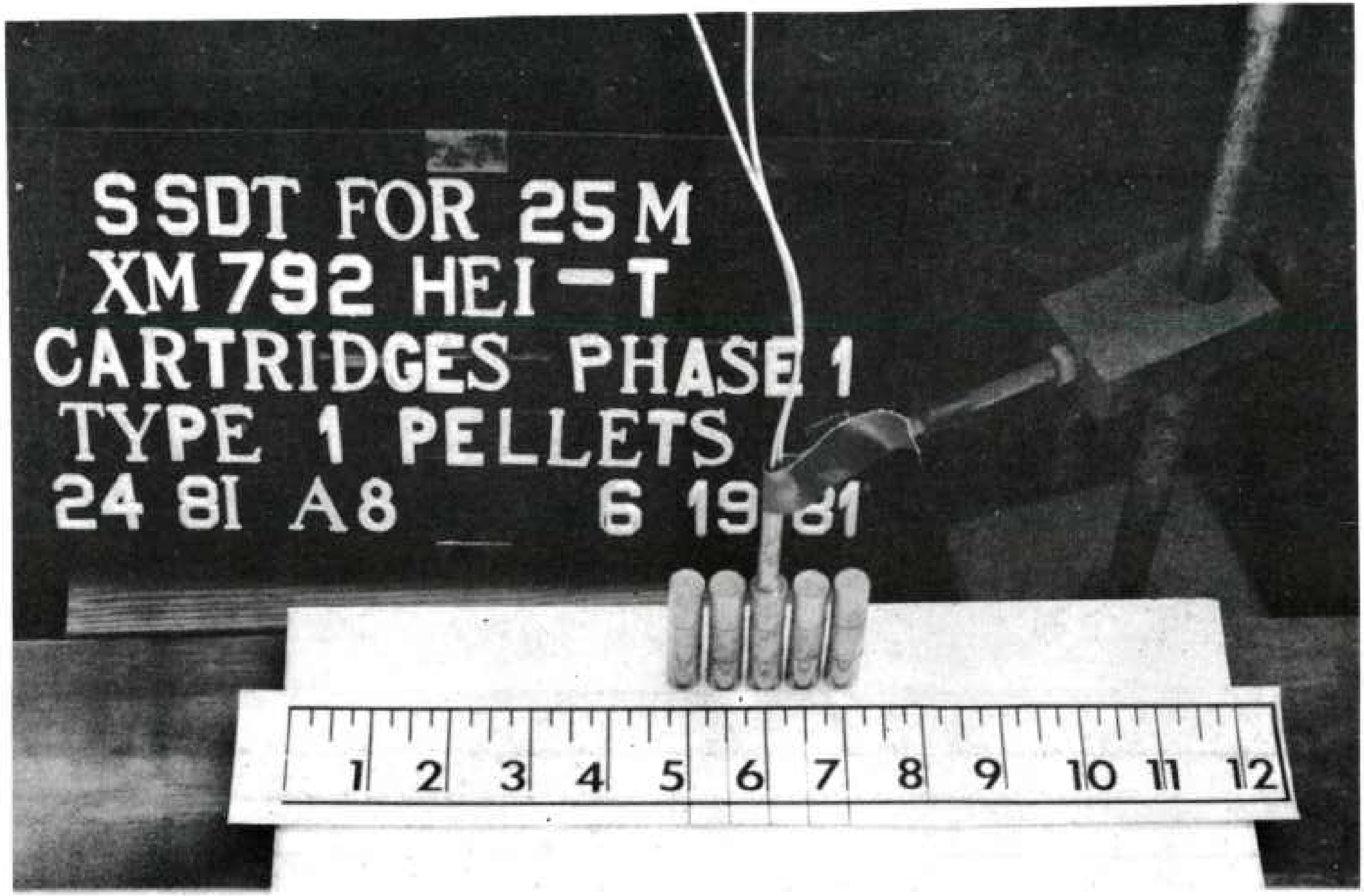

Figure 8. Pretest configuration - type I pellet (groups of three, stacked vertically)

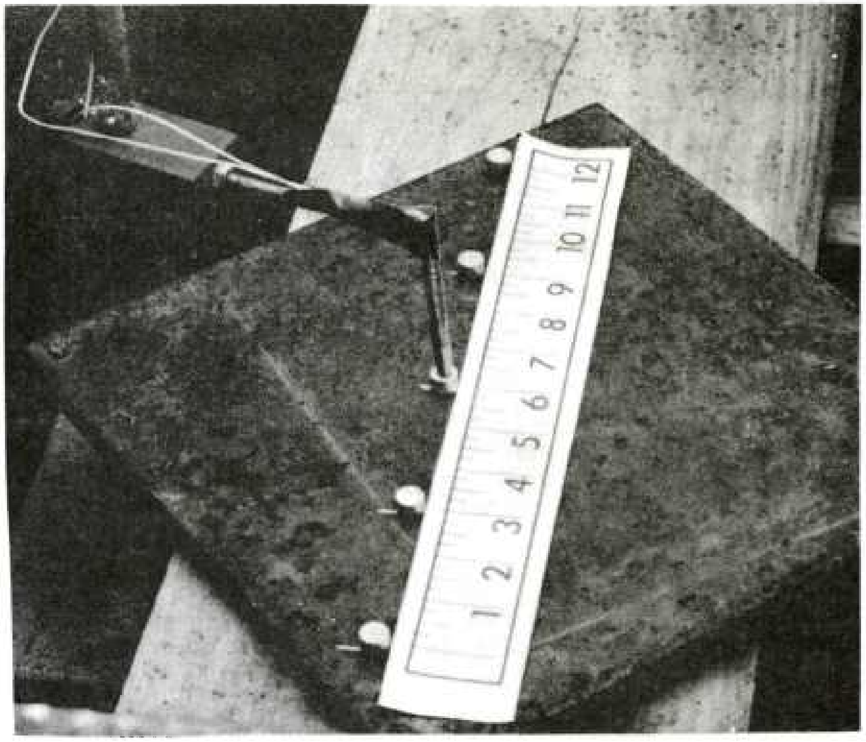

Figure 9. Pretest configuration - type II pellet

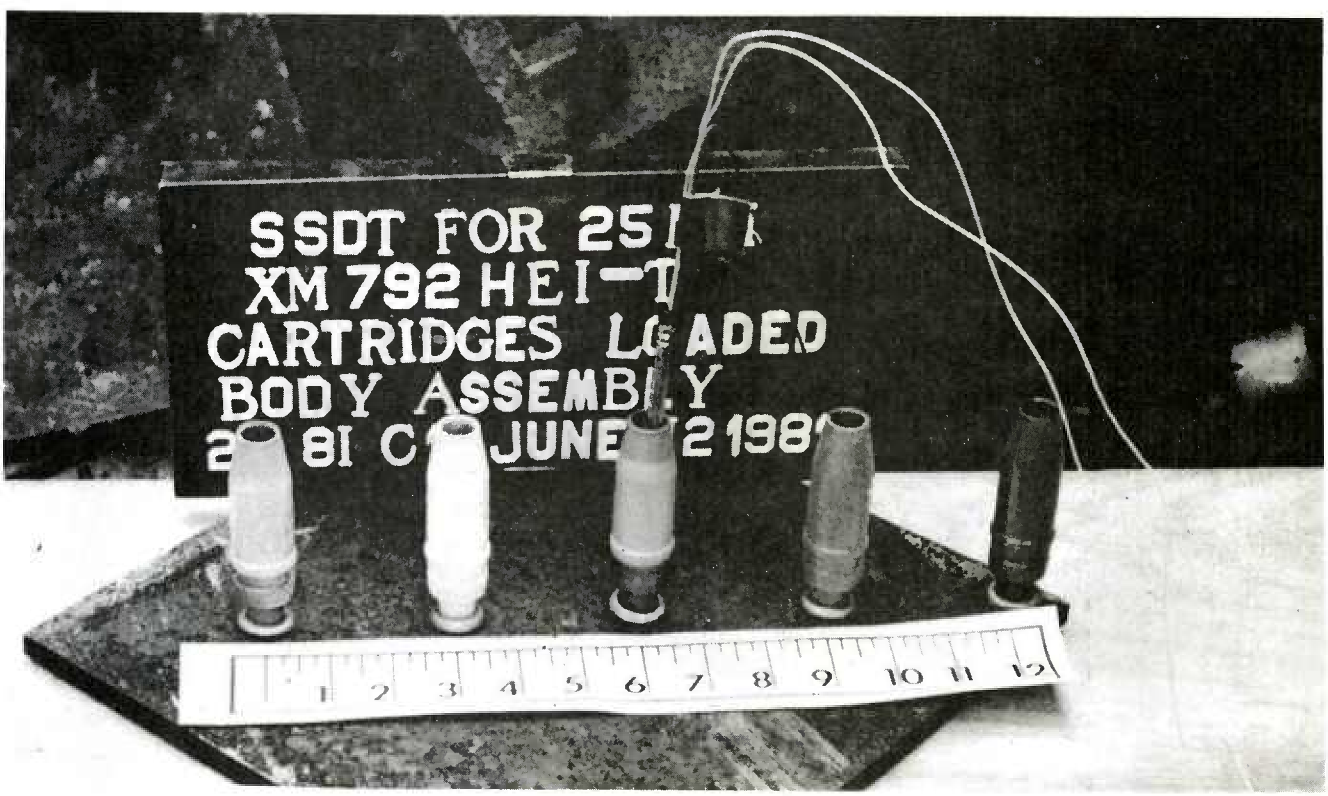

Figure 10. Pretest configuration - loaded body assembly

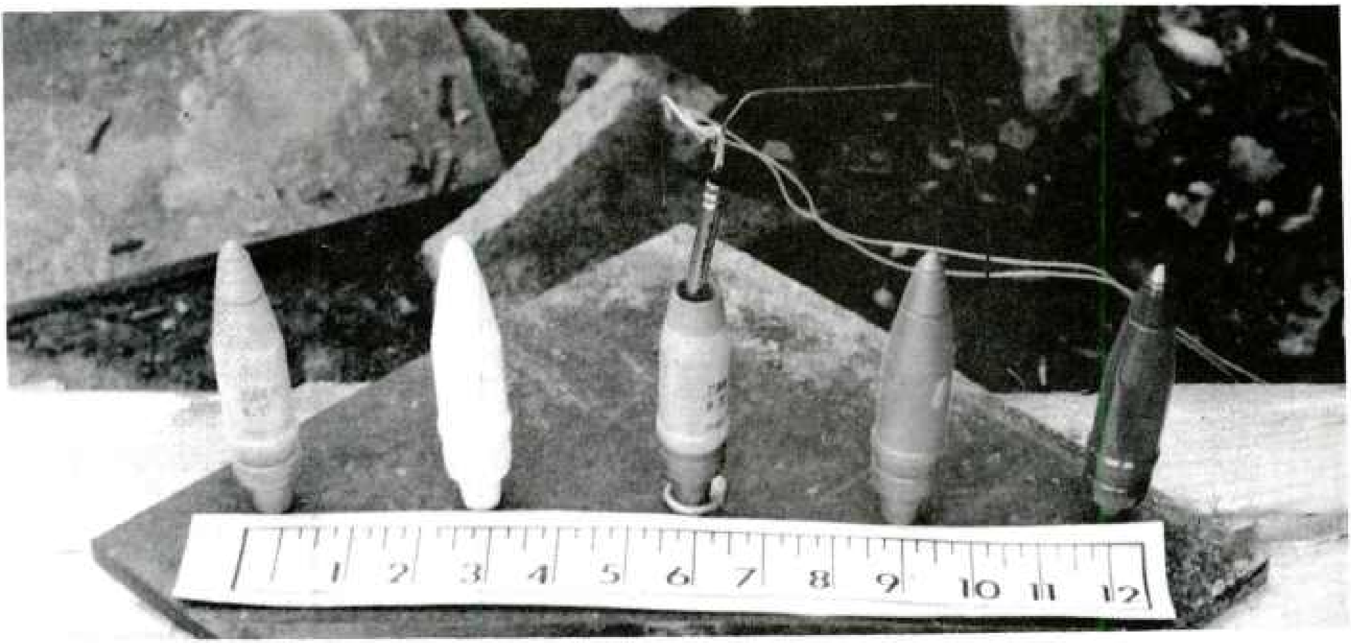

Figure 11. Pretest configuration - fuzed projectile

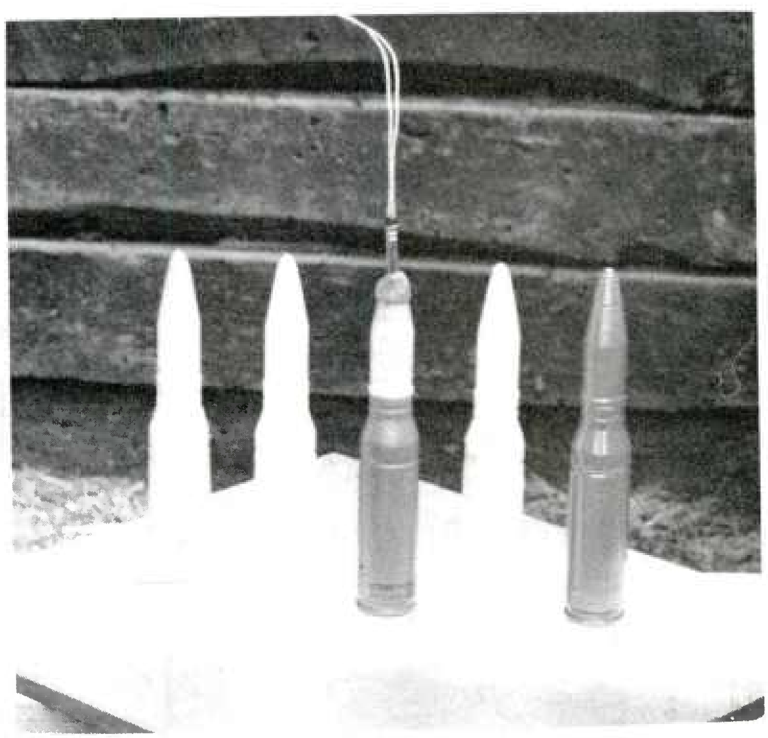

Figure 12. Pretest configuration - complete cartridge

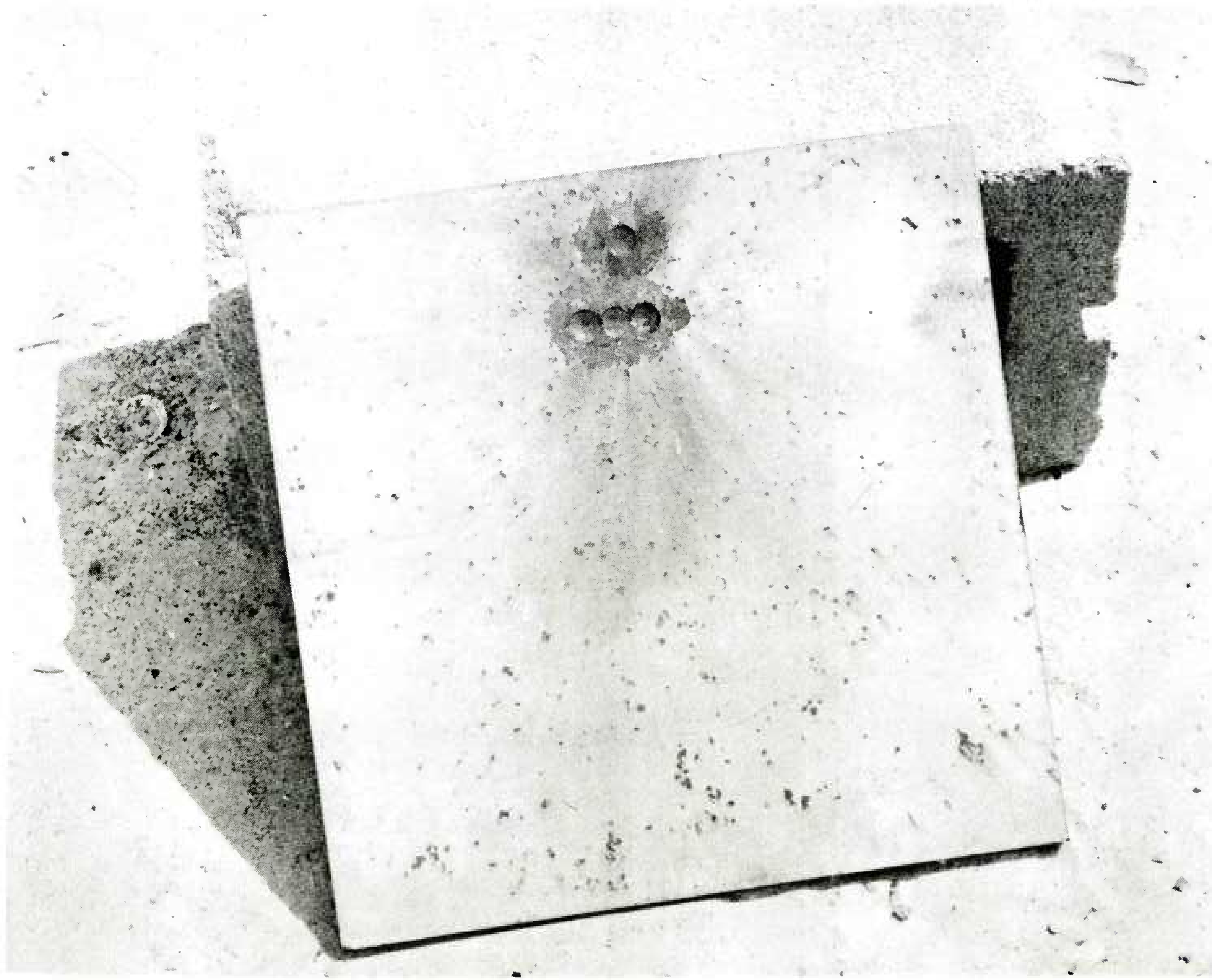

Figure 13. Posttest view - type I pellet (groups of three, stacked vertically), witness plate showing results of two tests

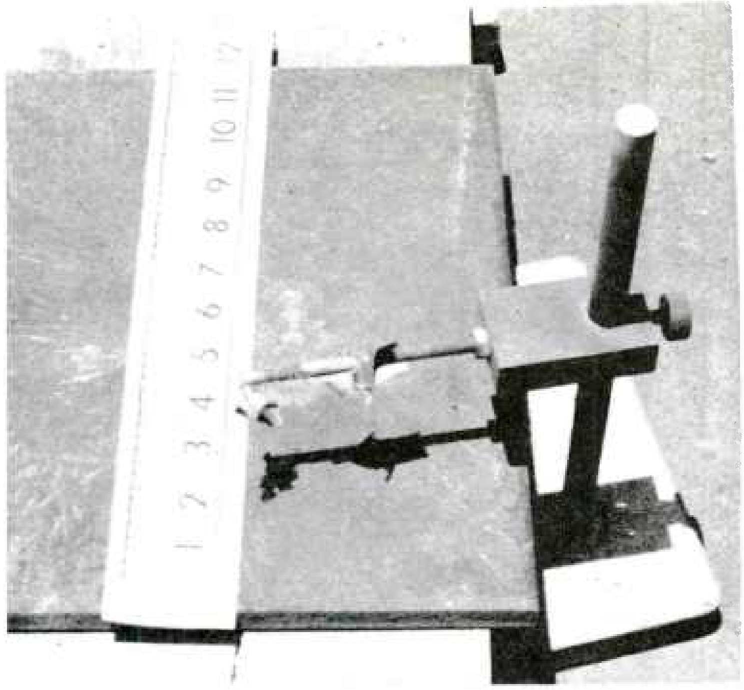

Figure 14. Posttest view - type II pellet, witness plate showing results of one test

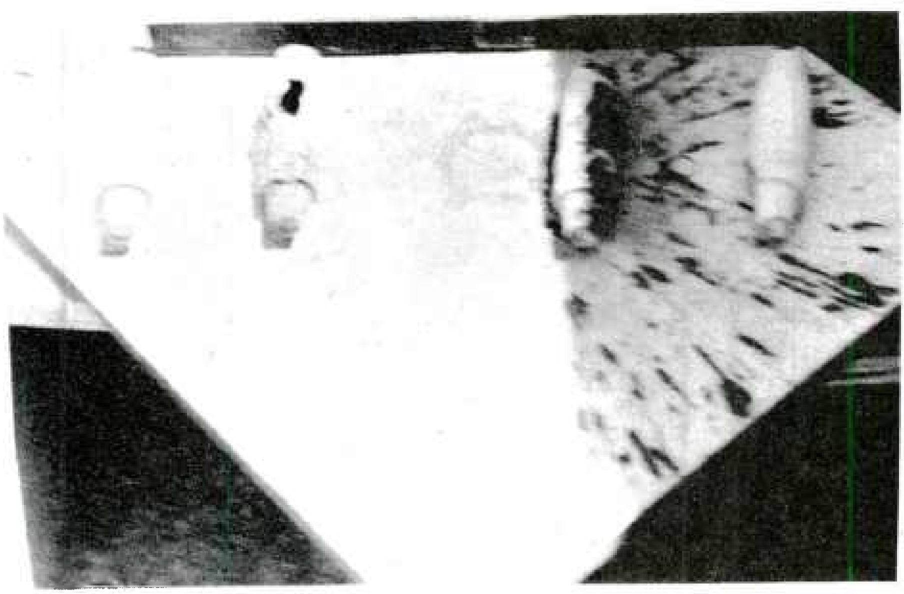

Figure 15. Posttest view - loaded body assembly

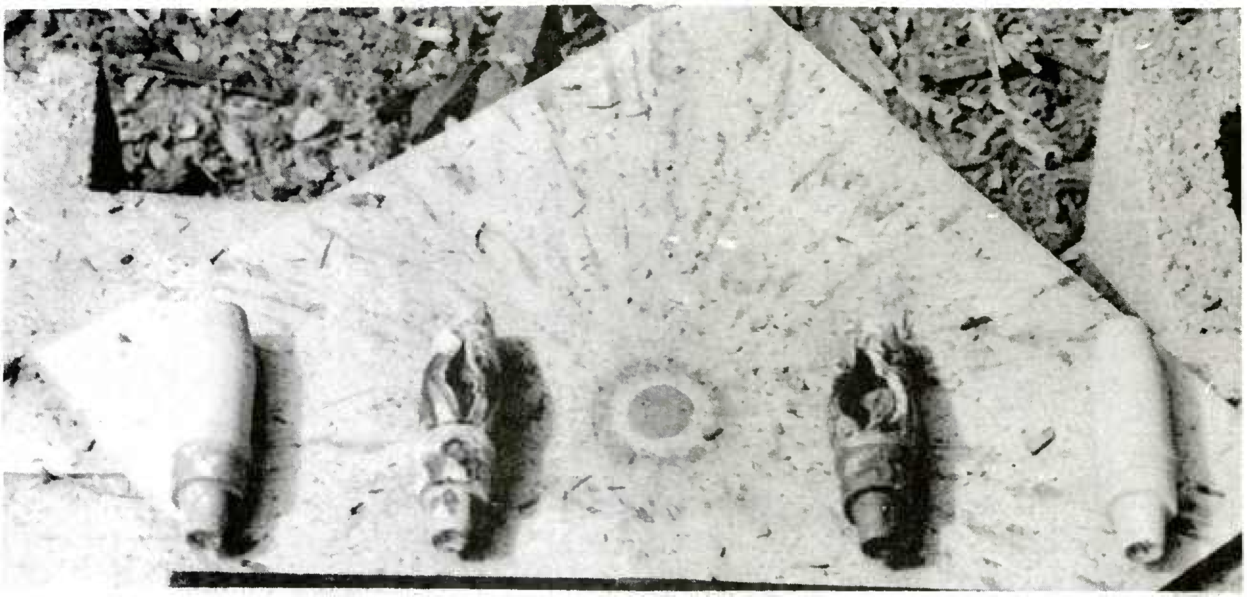

Figure 16. Posttest view - fuzed projectile

Figure 17. Posttest view - complete cartridge

APPENDIX

STATISTICAL EVALUATION OF EXPLOSION PROPAGATION

STATISTICAL THEORY

The probability of the occurrence of an explosion propagation is dependent upon the degree of certainty or confidence level involved and has upper and lower limits. The lower limit for all confidence levels is zero, whereas the upper limit is a function of the number of observations or, in this particular case, the number of acceptor items tested. Since each observation is independent of the others and each observation has a constant probability of a reaction occurrence (explosion propagation), the number of reactions (x) in a given number of observations (n) will have a binomial distribution. Therefore, the estimate of the probability (p) of a reaction occurrence can be represented mathematically by

$$p = x/n \tag{1}$$

and, therefore, the expected value of (x) is given by

$$E(x) = np \tag{2}$$

Each confidence level will have a specific upper limit (p_2) depending upon the number of observations involved. The upper probability limit for a given confidence level α, when a reaction is not observed, is expressed as

$$(1 - p_2)^n = \varepsilon \tag{3}$$

where

$$\varepsilon = (1 - \alpha)/2 \text{ and } \alpha < 1.0 \tag{4}$$

Use of equation 3 is illustrated in the following example:

<u>Example</u>

Determine the upper probability limit of the occurrence of an explosion propagation for a confidence level of 95% based upon 30 observations without a reaction occurrence.

<u>Given</u>

Number of Observations (n) = 30
Confidence Level (α) = 95%

<u>Solution</u>

1. Substitute the given value of (α) into equation 4 and solve for ε:

$\varepsilon = (1 - \alpha)/2 = (1 - 0.95)/2 = 0.025$

2. Substitute the given value of (n) and value of (α) into equation 3 and solve for p_2:

$$\varepsilon = 0.025 = (1 - p_2)^{30}$$

or

$$p_2 = 0.116(11.6\%)$$

CONCLUSIONS

For a 95% confidence level and 30 observations, the true value of the probability of explosion propagation will fall between zero and 0.116; or statistically, it can be interpreted that in 30 observations, a maximum of (0.116 x 30) = 3.48 observations could result in a reaction for a 95% confidence level.

Probability Table

Table A-1 shows the probability limits and the range of the expected value E(x) for different numbers of observations. Three confidence limits (90%, 95%, and 99%) are used to derive the probabilities. The same values are plotted in Figure A-1.

Table A-1. Probabilities of propagation for various confidence limits

Number of observations	90% confidence level		95% confidence level		99% confidence level	
n	P2	E(x)	P2	E(x)	P2	E(x)
10	0.259	2.59	0.308	3.08	0.411	4.11
20	0.131	2.62	0.168	3.36	0.233	4.66
30	0.095	2.85	0.116	3.48	0.162	4.86
40	0.072	2.88	0.088	3.52	0.124	4.96
50	0.058	2.9	0.071	3.55	0.101	5.05
60	0.049	2.92	0.060	3.6	0.085	5.10
80	0.037	2.96	0.045	3.6	0.064	5.12
100	0.030	3.0	0.036	3.6	0.052	5.2
200	0.015	3.0	0.018	3.6	0.026	5.2
300	0.010	3.0	0.012	3.6	0.018	5.4
500	0.006	3.0	0.007	3.5	0.011	5.5

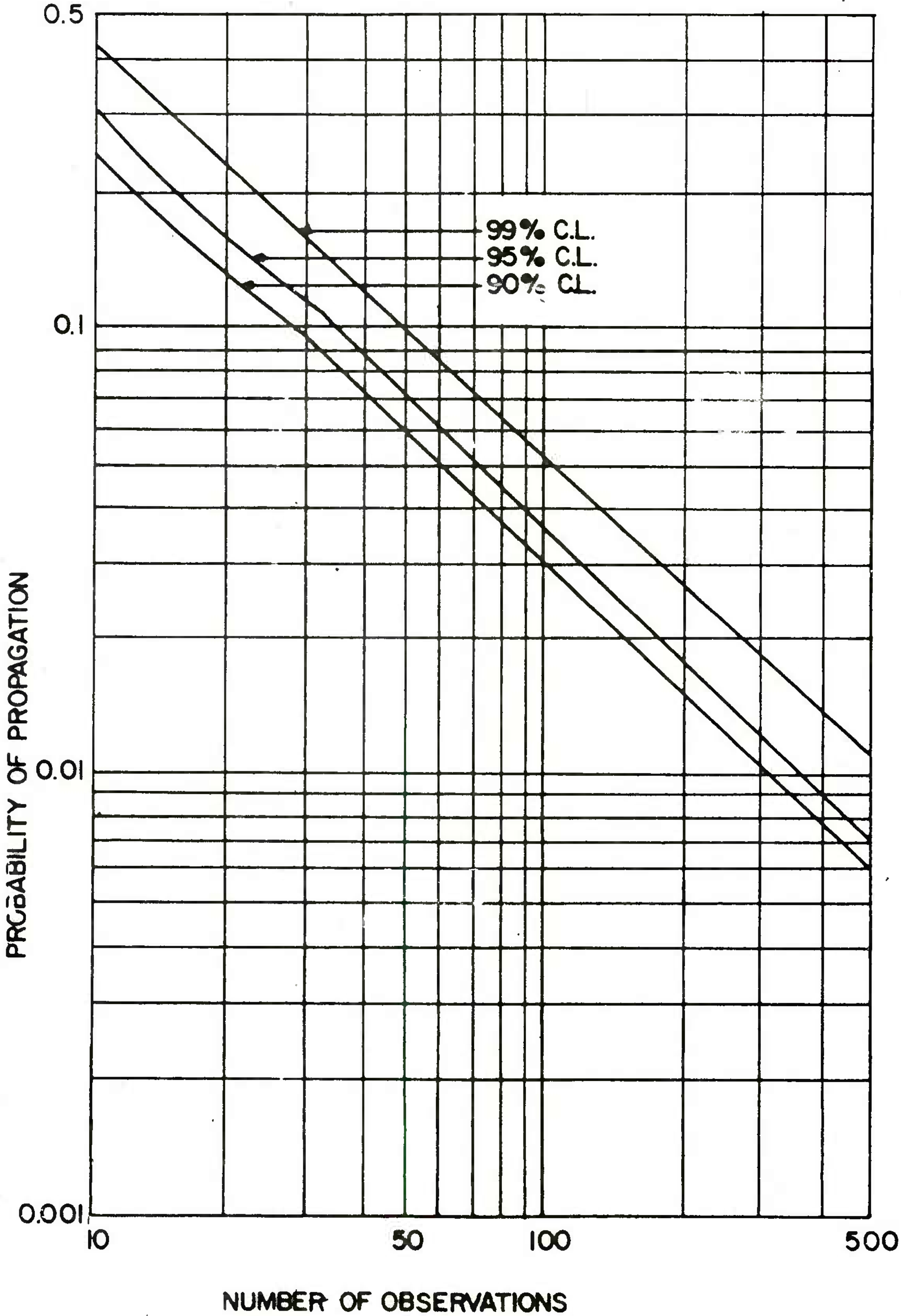

FIGURE A-1. Variations of propagation probability vs. number of observations as a function of confidence level.

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